RMI TITANIUM TECHNICAL BULLETIN
REACTIVE METALS INC., NILES, OHIO 44446 • PHONE 216 • 652-9951

RMI 3Al-8V-6Cr-4Mo-4Zr TITANIUM ALLOY FOR DEEP HARDENING APPLICATIONS (Reactive Metals, Inc.) 15 p

N79-79628

Unclas
00/26 32554

PRELIMINARY DATA SHEET

RMI 3Al-8V-6Cr-4Mo-4Zr TITANIUM ALLOY*

FOR DEEP HARDENING APPLICATIONS

BEST AVAILABLE COPY

This data is preliminary and represents initial information derived from one production heat of the alloy.

Customer Technical Services

January 1969

*Patent Pending

32554 158

PRELIMINARY DATA
RMI 3Al-8V-6Cr-4Mo-4Zr TITANIUM ALLOY
FOR DEEP HARDENING APPLICATIONS

Introduction:

The attached data was obtained from a 6-inch diameter billet produced from a production ingot of a new RMI titanium alloy. The alloy, designated as RMI 38644, is a highly beta-stabilized deep-hardenable alpha-beta alloy. Alloys of this type are normally called beta alloys; therefore, this terminology will be used. The preliminary data indicates that the alloy possesses attractive and uniform strength levels in sections up through 6 inches thick.

Physical Properties:

Beta transus, density, and modulus of elasticity values are shown in Table 1.

Tensile Property Data:

Full-section room-temperature tensile properties show excellent uniformity in the solution treated and solution treated and aged condition. Figures 1 and 2 illustrate this uniformity after air cooling and water quenching from the solution treating temperature on the full-section properties of RMI 38644 as solution treated and as solution treated and aged. Tables 2 and 3 include the longitudinal and transverse direction testing. Transverse ductility, although somewhat lower than desired, is the result of the fabrication procedure used. Additional work is underway to improve the transverse ductility through alternate processing procedures.

Fracture Toughness:

Preliminary fracture toughness test results (K_{Ic}) of the 6-inch round section are presented in Table 4. These data show the effect of quench rate from the solution temperature and direction of testing.

Figure 5 shows fracture toughness (K_{Ic}) versus tensile yield strength. This graph illustrates the typical toughness values taken from Military-Handbook-5. RMI 38644 and other alloys are plotted on this graph as well as the desired minimum fracture toughness values for a given yield strength as desired by two aircraft companies. Although the fracture toughness of RMI 38644 shows a good toughness value for the transverse test, it is believed that by revised processing further improvements in transverse toughness and ductility will be obtained.

The standard four-point loading specimen was used for all tests.

Heat Treatments:

Preliminary tests indicate that the best solution treating temperature for RMI 38644 is 1500F.

Figures 3 and 4 illustrate that a wide range of tensile properties can be obtained by varying the aging temperature-time combinations.

Plate and Sheet Products:

Evaluation of plate and sheet products made from laboratory ingots indicates attractive properties.

Table 5 shows a comparison of the tensile and fracture toughness properties of RMI 38644 plate with other high strength titanium alloys.

Table 6 shows the creep and thermal stability properties of RMI 38644.

TABLE 1

RMI 38644 TITANIUM ALLOY

Physical Property Data

Beta Transus (F)	1460F
Density lbs/in^3	0.174
Modulus of Elasticity (Tension) (STA Condition) $E_t \times 10^6$ psi	14.1

TABLE 2

RMI 38644 TITANIUM ALLOY

FULL-SECTION ROOM-TEMPERATURE TENSILE PROPERTIES
OF HEAT TREATED 6-IN. RD BY 6-IN. LONG SAMPLE

Location	UTS ksi	YTS 0.2% Offset ksi	% Elong. 1" Gage	R/A %
Treatment - 1500F/15 min. - water quench				
Longitudinal Direction				
Edge	119.7	114.1	16.0	41.9
Mid-Radius	119.6	113.4	9.5	21.7
Center	117.0	110.9	11.8	24.7
Transverse Direction				
Mid-Radius - End	120.2	114.2	7.5	25.2
Mid-Radius - 1 1/2-in. from End	121.6	115.7	4.8	11.3
Treatment - 1500F/15 min. - air cool				
Longitudinal Direction				
Edge	117.9	112.2	15.0	35.6
Mid-Radius	119.7	112.7	15.5	30.8
Center	119.8	112.8	14.0	33.4
Transverse Direction				
Mid-Radius - End	121.6	115.5	7.3	23.0
Mid-Radius - 1 1/2-in. from End	124.3	117.7	9.5	23.0

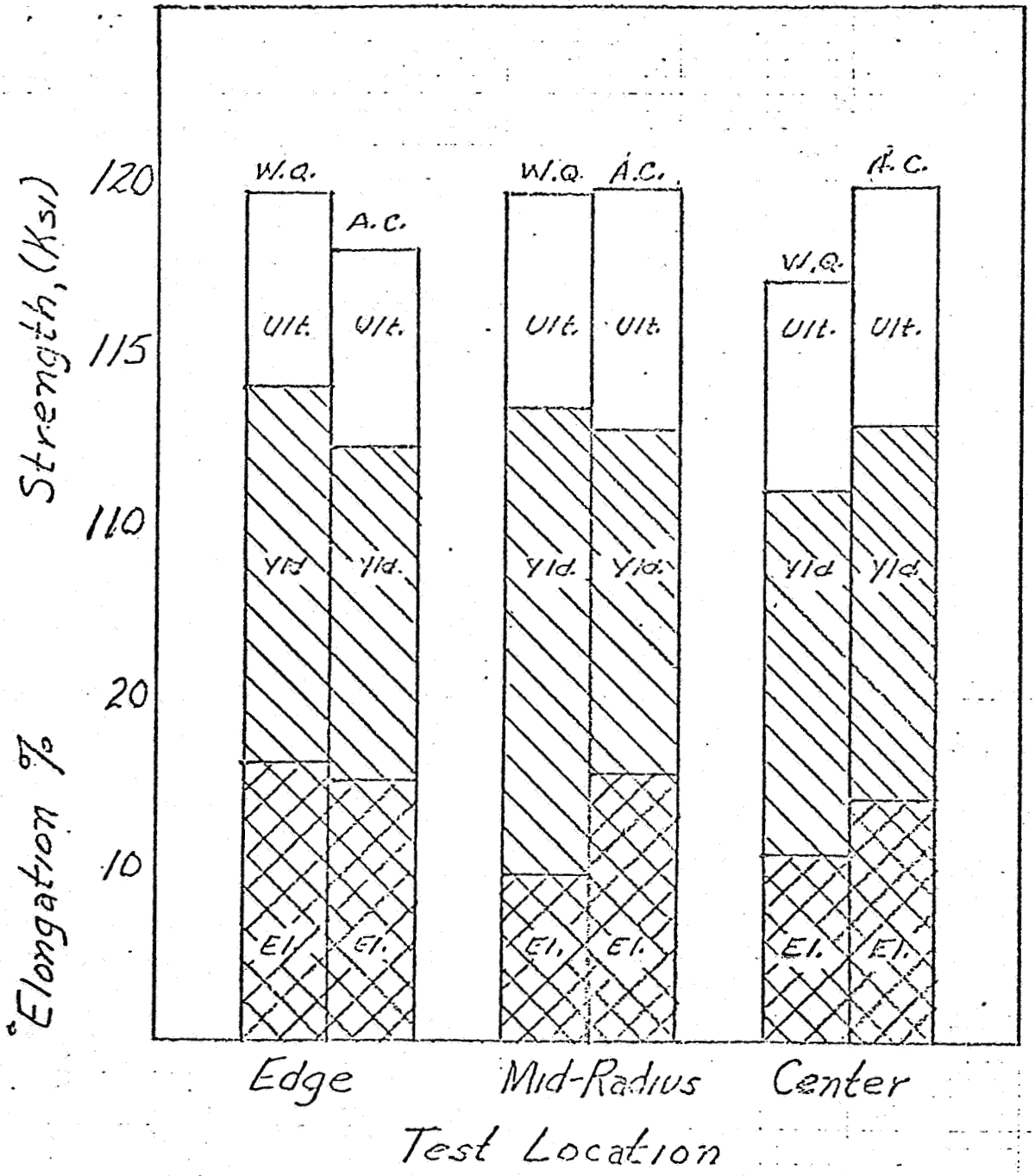
Figure 1

RMI - 38644 Titanium Alloy

Effect Of Quench Rate And Test Location On Full Section Rm. Temp. Tensile Properties(1)

6 in. Rd. Billet

Treatment: 1500F/15Min. - Cool(2)



Note:
(1) All Tests Longitudinal - Avg. 2 Specimens.
(2) W.Q = Water Quench A.C. = Air Cool

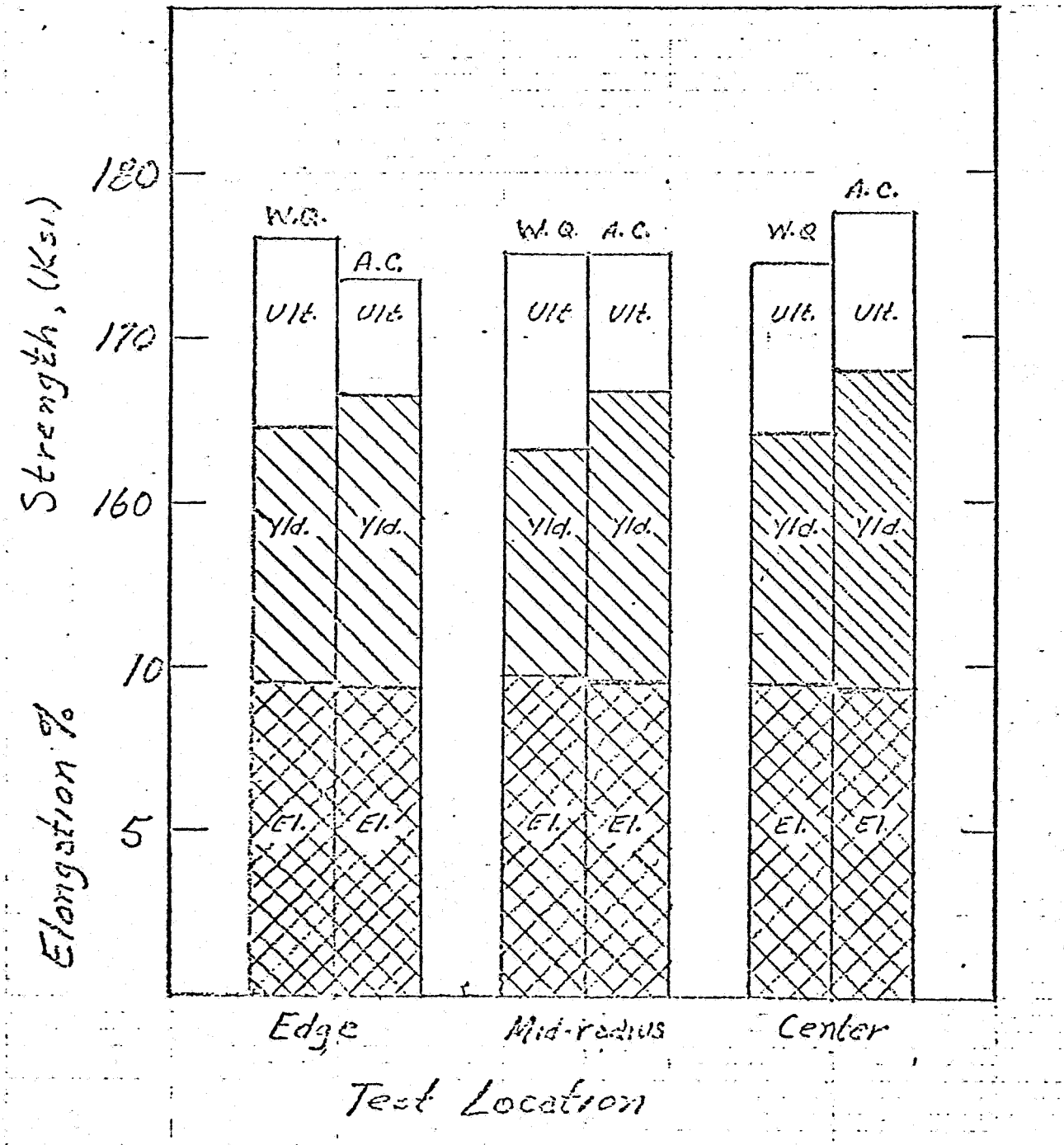
Figure 2

RMI-38644 Titanium Alloy

Effect Of Quench Rate And Test Location On Full Section Rm. Temp. Tensile Properties[1]

6 in. Round Billet

Treatment: 1500F/15 Min. - Cool[2] + 1050F/12 Hr - A.C.



Note (1) All Tests Longitudinal - Average 2 Specimens

(2) W.Q = Water Quench A.C. = Air Cool

TABLE 3

RMI 38644 TITANIUM ALLOY

FULL SECTION ROOM TEMPERATURE TENSILE PROPERTIES
OF HEAT TREATED 6-IN. RD BY 6-IN. LONG SAMPLE

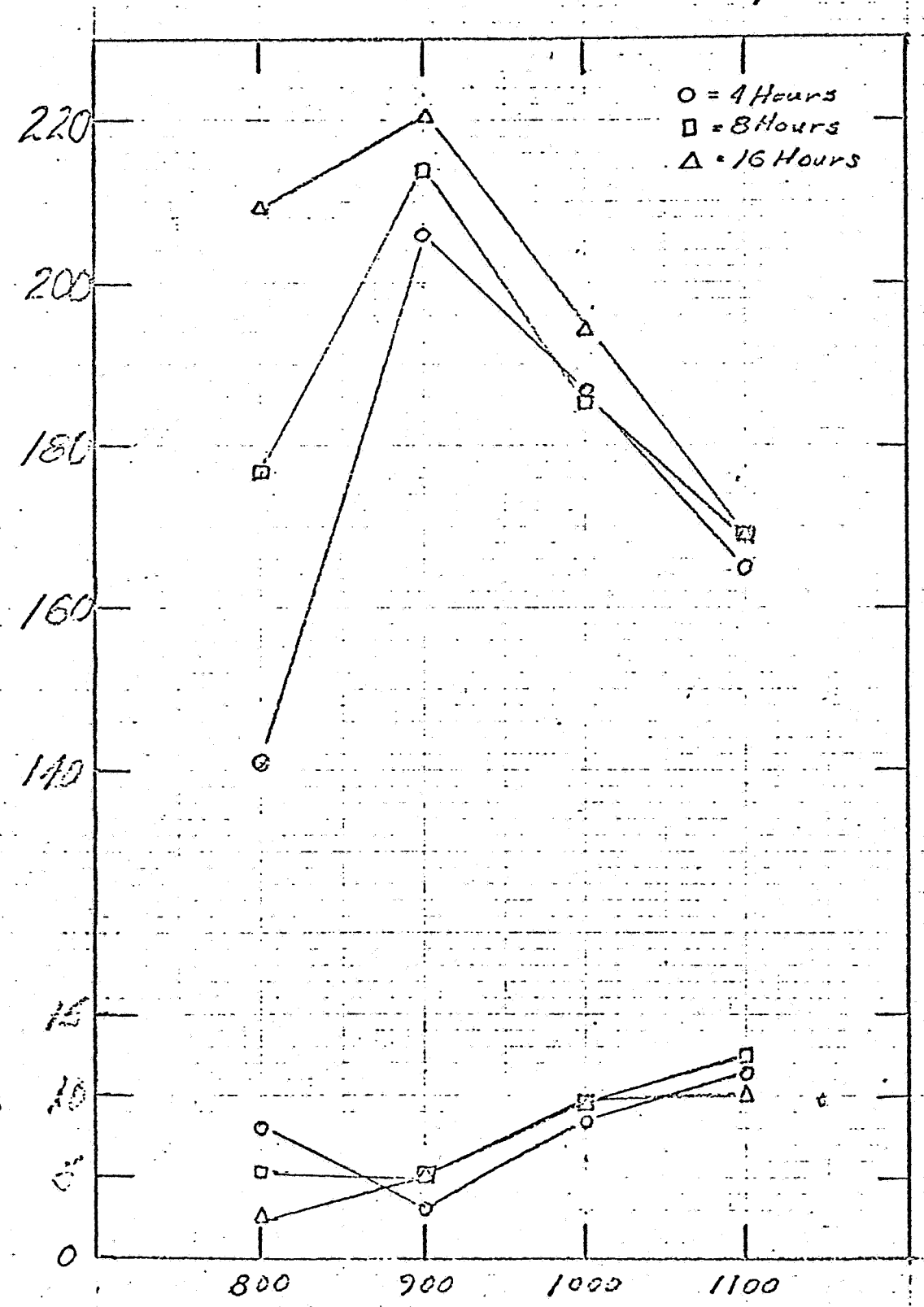
Location	UTS psi	YTS 0.2% Offset psi	% Elong. 1" Gage	R/A %
Treatment - 1500F/15 min. - water quench; aged 1050F/12 hrs. - air cool				
Longitudinal Direction				
Edge	176,100	164,500	9	17.6
Mid-Radius	172,500	163,200	9	19.6
Center	174,400	163,800	9	18.0
Transverse Direction				
Mid-Radius - End	170,200	162,800	3	6.5
Mid-Radius - Mid-Length	172,400	166,000	3	5.6
Treatment - 1500F/15 min. - air cool; aged 1050F/12 hrs. - air cool				
Longitudinal Direction				
Edge	173,300	166,500	8	18.2
Mid-Radius	175,200	166,800	9	17.4
Center	177,700	168,000	8	16.0
Transverse Direction				
Mid-Radius - End	180,100	171,400	3	5.9
Mid-Radius - Mid-Length	180,200	171,700	3	6.6

Figure 3

RMI 38644 Titanium Alloy

Effect of Aging Temp. At Various Times On Rm. Temp. Tensile Properties (1)

Solution Treatment 1500F/15 Min.-A.C.



Note: Upset Forge $2\frac{1}{2}$"th. To $\frac{5}{8}$"th. - 1500F Furnace

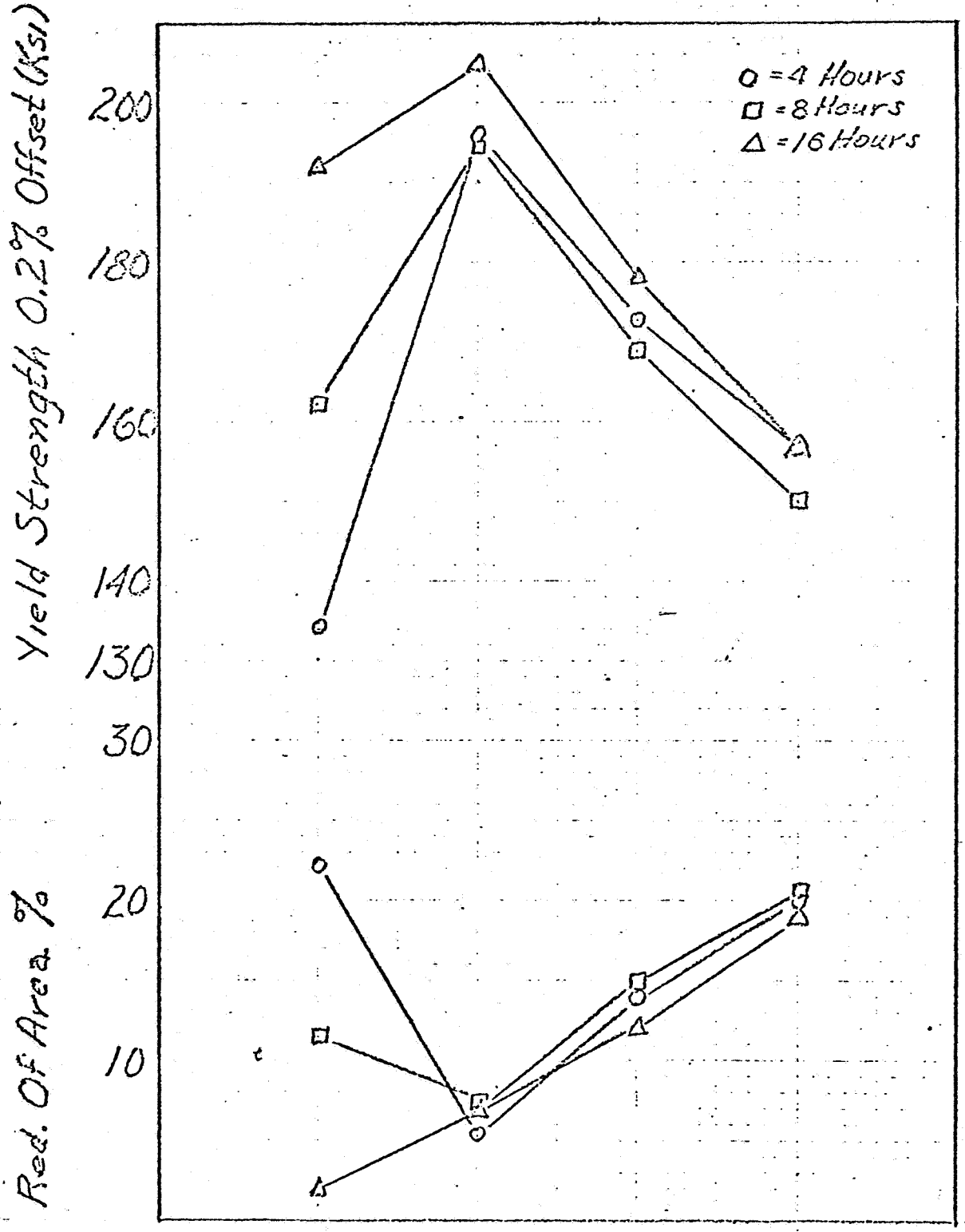
Figure 4

RMI 38644 Titanium Alloy

Effect of Aging Temp At Various Times

On Rm. Temp Tensile Properties(1)

Solution Treatment - 1500F/15Min.-A.C.



Note: Upset Forge $2\frac{1}{2}$" th. To $\frac{5}{8}$" th. - 1500F Furnace

Figure 5

Fracture Toughness (K_{Ic}) Versus Yield Strength

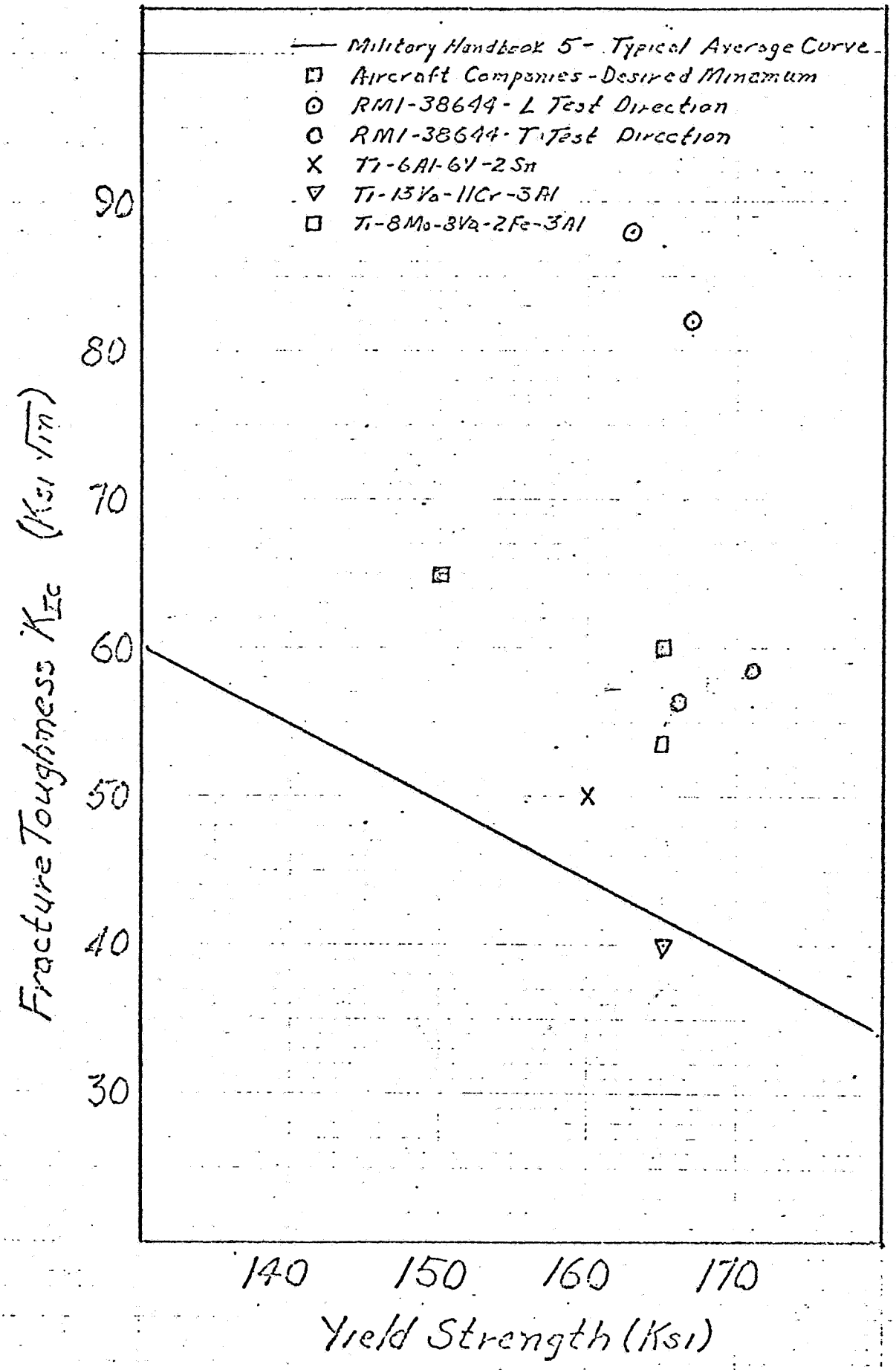


TABLE 4

FRACTURE TOUGHNESS OF RMI 38644 ALLOY
6-IN. RD BILLET, MID-RADIUS LOCATION

Treatment (1)	Test Direction	K_{Ic} (ksi$\sqrt{in}$)	UTS (ksi)	YTS (ksi)	Elong. (%)	R/A (%)
Water Quench	L	88.0	172.5	163.2	9.5	19.6
Water Quench	T	56.4	172.4	166.0	3.0	5.6
Air Cool	L	81.8	175.2	166.8	9.2	17.4
Air Cool	T	57.6	180.2	171.7	3.5	6.6

(1) Solution Treated 1500F/15 min. - Cooled - (Water Quench - Air Cool)
Age 1050F/12 hrs. - Air Cool

Specimen: Four-Point Loading

TABLE 5

SIMULATED LARGE SECTION PROPERTIES
(0.750" PLATE)

Alloy Composition	Heat Treatment	UTS ksi	YS ksi	El %	RA %	K_{Ic} ksi$\sqrt{in}$
IMI 680 (Ti-11Sn-2.25Al-4Mo-0.25Si)	1500F-1Hr-AC; 930F-24Hr-AC	172	153	8	18	69
IMI 700 (Ti-6Al-5Zr-3Mo-1Cu-0.25Si)	1705F-1Hr-AC; 930F-24Hr-AC	178	162	7	15	64
*Ti-6Al-6V-2Sn	1650F-1Hr-AC; 975F-4Hr-AC	166	155	13	42	51
RMI 38644	1500F-1Hr-AC; 975F-4Hr-AC	185	175	8	17	82

*Rolled product, others forged.

TABLE 6

THERMAL STABILITY OF EXPERIMENTAL ALLOY (SHEET)

	Before Creep			Creep Exposure				After Creep		
Alloy	UTS ksi	YS ksi	El %	Temp. F	Stress ksi	Time Hrs.	Def. %	UTS ksi	YS ksi	El %
RMI 38644	195	179	7	600	115	96	0.41	201	192	5
	174	158	9	600	65	96	0.08	177	160	7
	161	146	11	600	55	96	0.06	162	150	12

Table 1

TENSILE, SHEAR, AND HEADABILITY PROPERTIES
OF RMI 38644 FASTENER STOCK

ze	Condition	YS ksi	UTS ksi	El. (%)	RA %	Double Shear ksi	Cold Head Ratio D_f/D_I*
625	1500F-15min-AC	123.7	129.2	18	52	93.5	1.95
600	1500F-15min-AC	126.1	128.7	15	40	93.5	2.02
	1500F-15min-AC	123.7	126.1	16	42	95.7	2.05
	1500F-15min-AC + 950F-6hrs-AC	175.5	194.0	9	17	112.3	--
	1500F-15min-AC + 950F-6hrs-AC	180.0	198.0	9	23	110.2	--
	1500F-15min-AC + 1000F-6hrs-AC	165.2	178.5	10	23	--	--
	1500F-15min-AC + 1000F-6hrs-AC	163.7	178.3	10	23	--	--
	1500F-15min-AC + 1050F-6hrs-AC	162.7	177.1	13	33	110.5	--
	1500F-15min-AC + 1050F-6hrs-AC	157.3	172.0	14	38	112.7	--
575	1500F-15min-AC + 1050F-6hrs-AC	156.5	168.6	18	47	--	--
	1500F-15min-AC + 1050F-6hrs-AC	155.6	166.7	18	50	--	--
530	C.D.* 20%	158.6	165.2	11	46.5		
		155.8	164.5	15	40.0		
512	C.D. + 1500F-15min-AC	129.6	130.7	16	49	92.0	2.06
	C.D. + 1500F-15min-AC	127.2	129.4	16	49	91.3	2.06
	1500F-15min-AC + 1050F-6hrs-AC	151.4	163.3	15	50	104.3	--
	1500F-15min-AC + 1050F-6hrs-AC	152.5	161.3	13	49	101.8	--
548	C.D. + 1500F-15min-AC	136.7	141.0	13	54	89.6	2.44/2.23
	C.D. + 1500F-15min-AC	138.1	141.7	15	53	89.9	2.42/2.14
	1500F-15min-AC + 1050F-6hrs-AC	144.4	159.9	13	46	105.3	--
	1500F-15min-AC + 1050F-6hrs-AC	145.5	159.9	17	49	106.6	--
530	C.D. + 800F-6hrs-AC	226.6	241.0	5	16.6		
		228.3	242.4	5	17.8		
	C.D. + 900F-6hrs-AC	214.8	229.5	5	15.1		
		214.5	229.1	5	17.5		
	C.D. + 1000F-6hrs-AC	178.2	191.6	12	16.4		
		176.4	189.3	12	19.3		
537	C.D. + 1500F-15min-WQ	125.0	126.8	27.0	50.0	93.8	1.77
		125.7	127.5	27.0	53.0	93.5	2.01
	1500F-15min-WQ + 1050F-6hrs-AC	151.4	161.8	17.0	43.0	108.0	--
		152.7	162.0	20.0	45.0	109.0	--
	1500F-15min-WQ + 1250F-6hrs-AC	125.9	130.6	12.0**	26.0	95.4	1.88
		126.8	132.0	20.0	28.0	96.8	1.68

C.D. = Cold Drawn
D_f = Final Diameter
D_I = Initial Diameter

** Broke outside gage mark.

PROPERTIES OF RMI 38644 TUBING

Heat Treatment	Size	Yield ksi	UTS ksi	El. (%)	Flare (%) (60°)	Flat
1500-15min-AC	.750" OD x .036" W	131.9	131.9	22	36	8T
" " 900-6hrs-AC	" " " "	191.2	204.7	4		
" " 1050-6hrs	" " " "	156.8	163.4	-		
		170.7	180.3	14		
" " 1250-6hrs	" " " "	135.9	140.5	17		
		128.2	132.6	17		
1500-15min-AC	1.50" OD x 0.160" W	126.8	129.5	13		
		129.6	131.2	14		
1500-15min-AC	2.625" OD x .375" W (Shell)	120.7	123.1	24		
		118.6	120.9	26		

PROPERTIES OF BETA M TUBING

1500-15min-AC	.750" OD x .036" W	123.2	128.7	10	44	12T
		125.8	131.3	12		
" " 1050-6hrs-AC	" " " "	161.7	173.4	12		
" " 1250-6hrs-AC	" " " "	139.3	152.6	11		
		150.2	162.9	15		
1500-30min-Vac	1.50" OD x 0.158" W	121.8	125.9	12		
		122.8	125.0	-		
1500-15min-AC	2.625" OD x .375" W (Shell)	112.9	118.7	18		
		111.6	118.5	18		